The Science of **Construction**

Science around us series, booklet - III

The Science of CONSTRUCTION

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The Science of Construction

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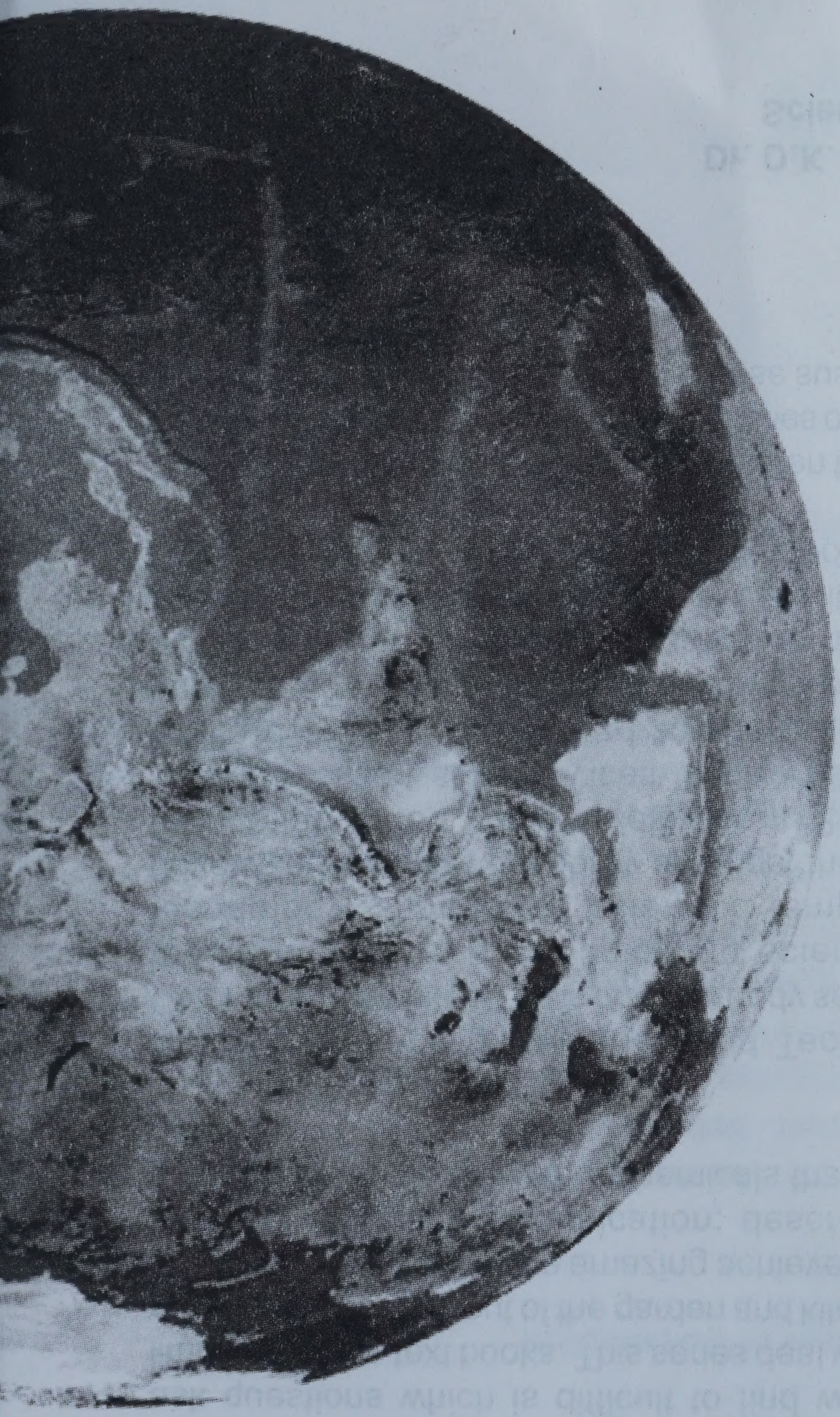
FOREWORD

The young mind is ever inquisitive, sometimes they ask questions which is difficult to find within the limitation of the text books. This series deal with such questions emerging out of the garden and kitchen and other places; describe the amazing achievements in the field of S&T communication; describes the alternatives to the danger of chemicals that we use daily.

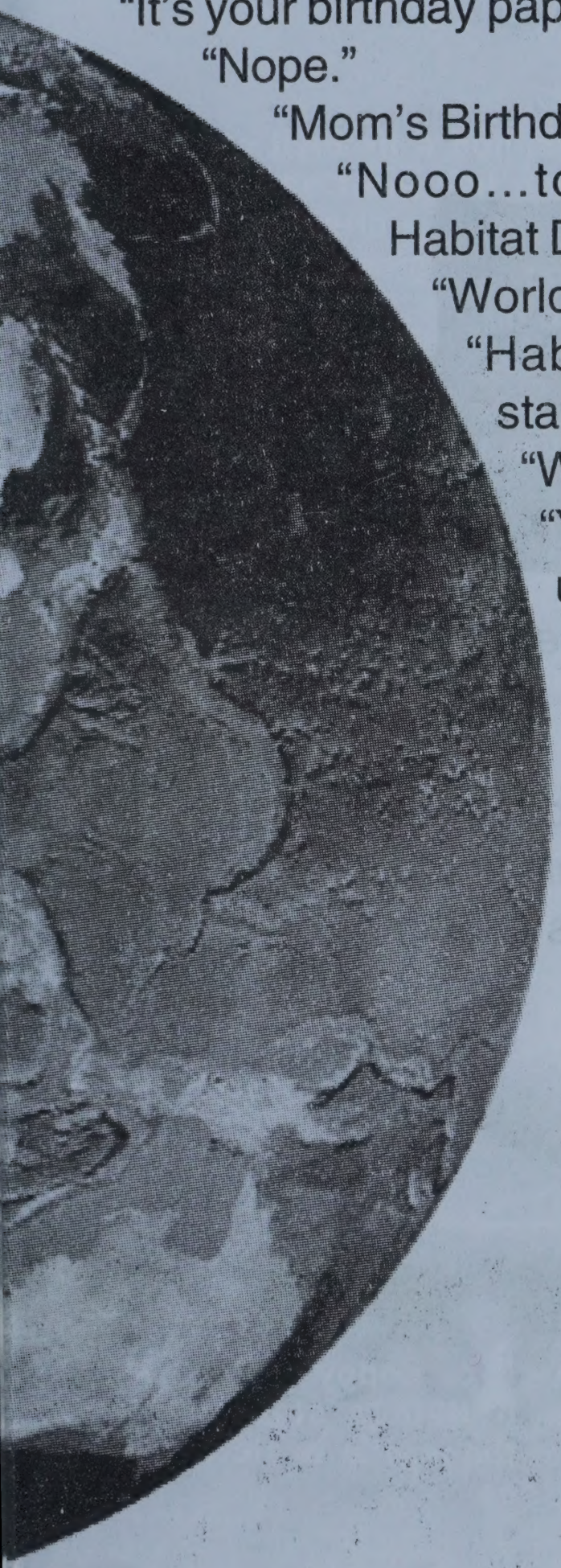
National Council for Science and Technology Communication (NCSTC) is an apex body set up with the objectives of communicating science and technology, stimulating scientific temper and developing scientific capability amongst the people has collaborated with Development Research Communication and Services Centre (DRCSC), Kolkata, which is devoted to spreading and popularizing environment science amongst people for last 25 years to bring out this series to demystify scientific phenomenon of science in daily life for the children. Hope the grown up will enjoy it too.

We trust that this will encourage the children to search for larger picture, dig deep in to the mysteries of science & successes of technology and of course sustainable living alternatives.

Dr. D.K. Pandey
Scientist 'E'



Chapter 1 Why we need houses



"Sunny, today is 6th October. Do you know why this day is important?"

"It's your birthday papa.

"Nope."

"Mom's Birthday?"

"Nooo...today is World Habitat Day."

"World....What?"

"Habitat...habitat is where we stay."

"We stay in the building"

"Yes, that is true, but if we open up our thinking, then the Earth is our home - we all live here.'

Earth is our home, where we live in. We have numerous neighbours, right from human beings in other countries to animals, birds, insects and numerous other living creatures present on this only planet, which is habitable in the solar system.

And we must learn to be cautious about this 'home' and its inhabitants. Any any action we take should not jeopardize life and living environment on this planet.

What do earth provides us with ?

1. Land to live on
2. Natural shelters like caves, tree trunks etc.
3. Air to breathe
4. Water to drink
5. Food

Can you think of something else?

And what are we doing in return?

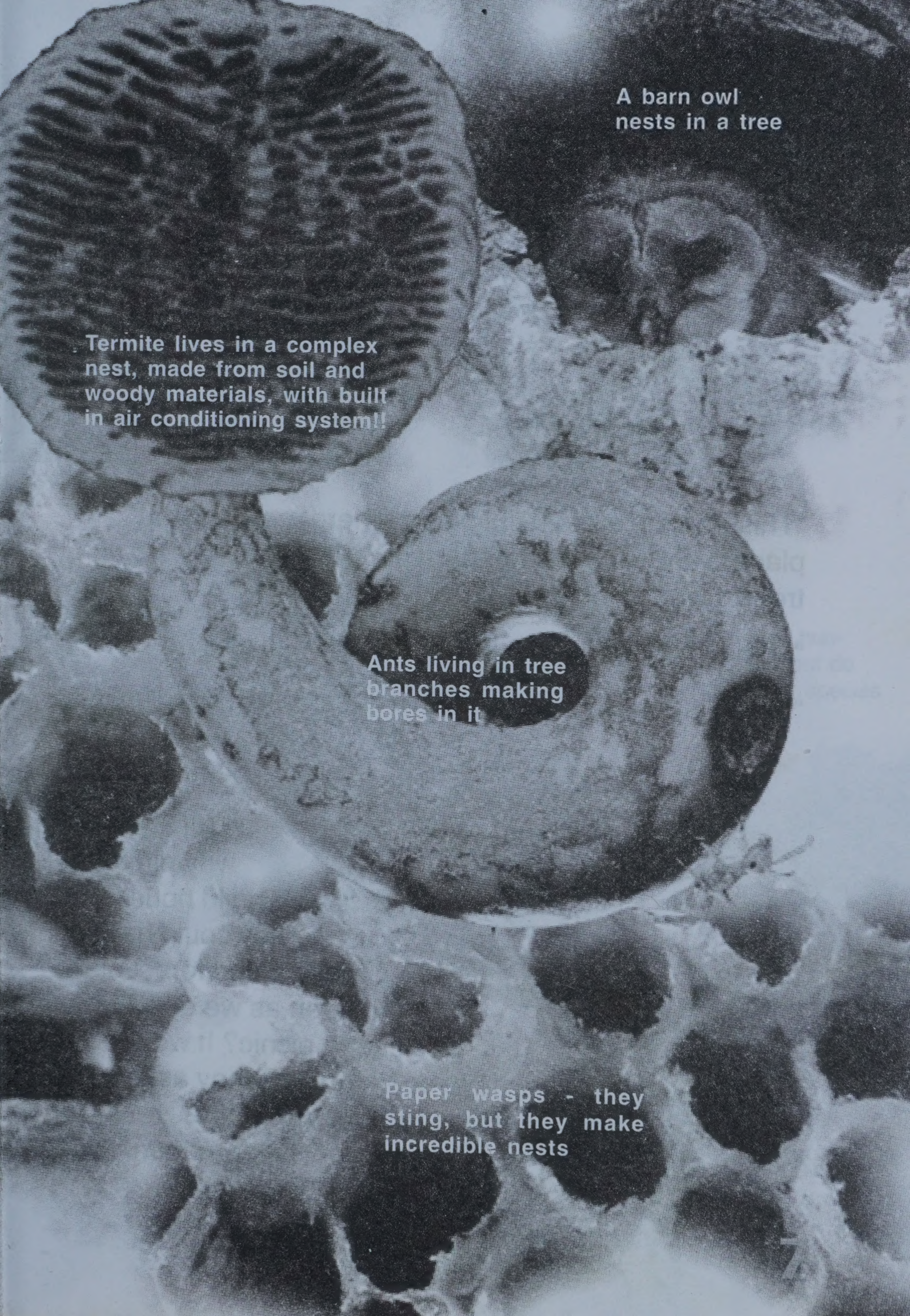
1. Cutting down the trees! Thus leaving fertile land barren to get weathered off
2. Polluting the air.
3. Polluting water
4. Using harmful chemicals that damage web of life

"Can you suggest how we can be more careful, Sunny?" – Papa asked.

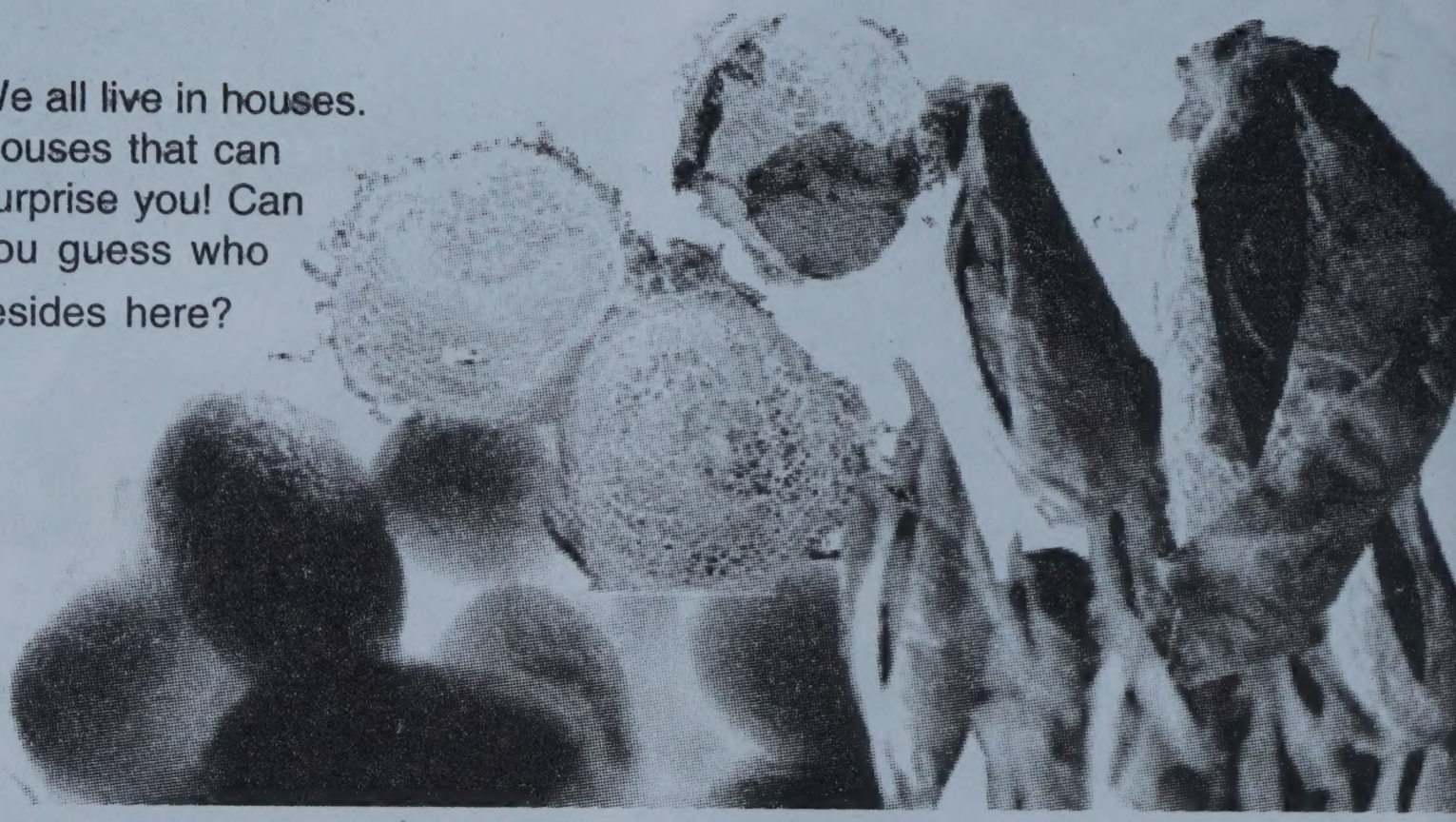
Sunny was thinking. Thinking about the nest that a small sparrow had built in the ventilator! The littles were always shouting chick chick chick...

Nest of a weaver bird

House for poppy seeds ... May be human beings started thinking from these, the basic concept of houses


A barn owl nests in a tree
Termite lives in a complex nest, made from soil and woody materials, with built in air conditioning system!!
Ants living in tree branches making bores in it
Paper wasps - they sting, but they make incredible nests

We all live in houses. Houses that can surprise you! Can you guess who resides here?

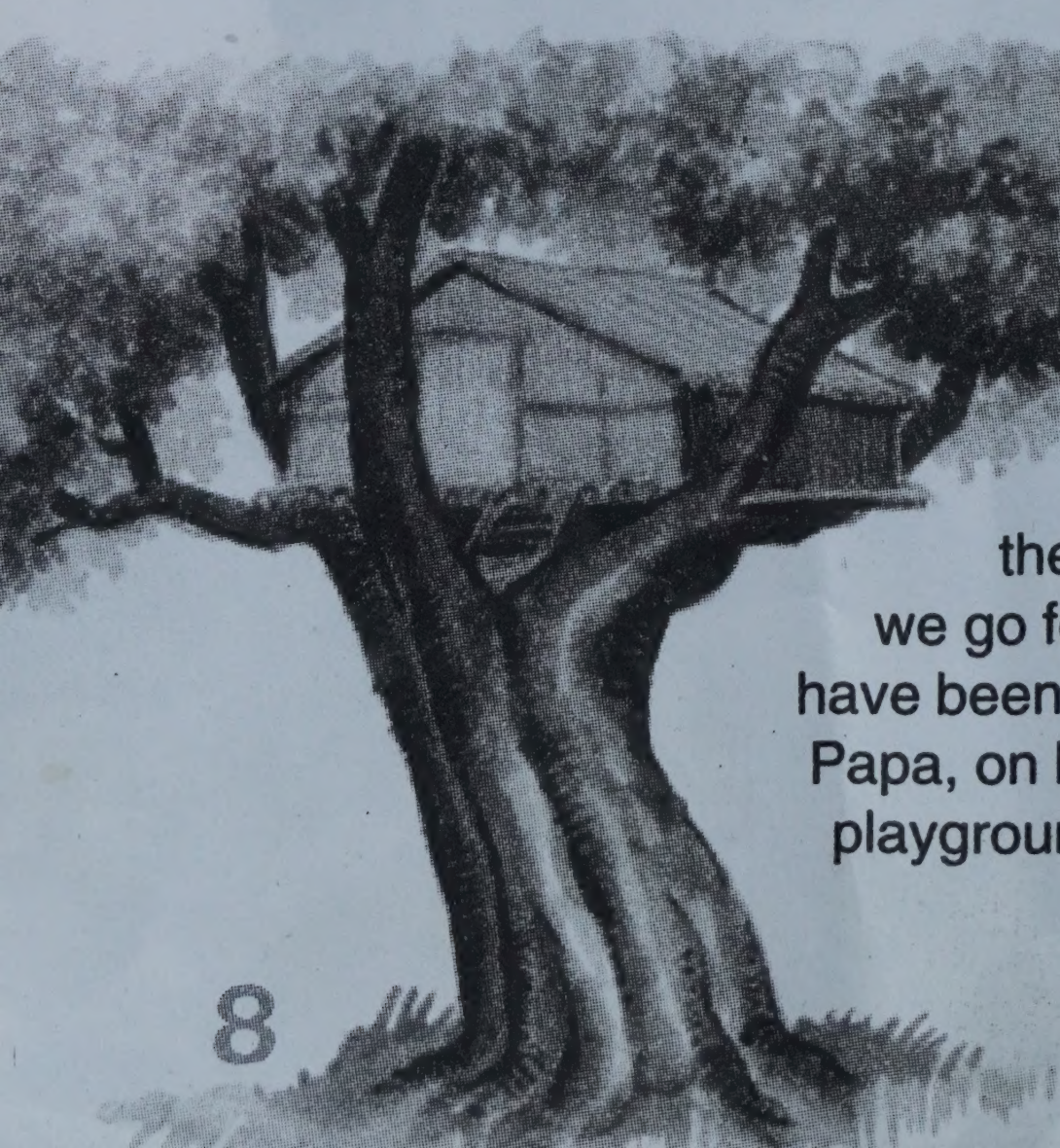


"This earth is a beautiful place. There are very hot places, and very cold ones. There are thick forests of trees....and concrete!"

"I have read in a book that Africans live in tree houses"

"Not all dear. Some who live in the forest, might live in a tree house"- papa replied.

"But Papa, why did man build houses? They could have lived in the forest or in the open as we do when we go for a picnic? It would have been fun" – Sunny asked Papa, on his way to the playground in the aftrenoon.



Igloos in Antarctica are made of ice blocks. Can you believe human beings live here !

War bombing devastated hundreds of human habitats but do you know how many tiny species lost there homes?

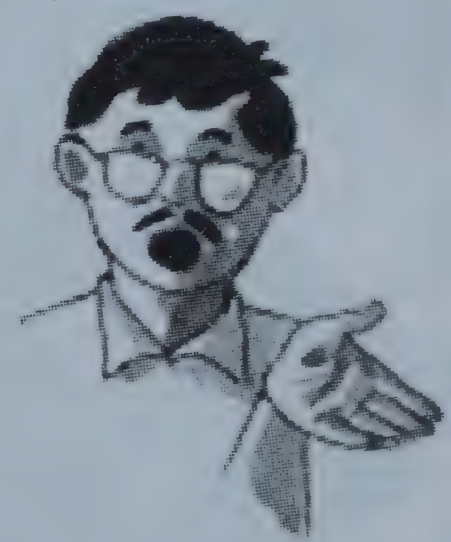
Houses of Jaisalmer, made of yellow sandy soil and yellow sandstone

"Well, great idea! Let's stay out today. Ask Mom to make food for us. You go out, I will join you soon" – Papa agreed.

It was monsoon. Suddenly It started to rain heavily late in the afternoon.

Sunny came back running. "No Papa, not today. We will stay outside when it will not be raining."

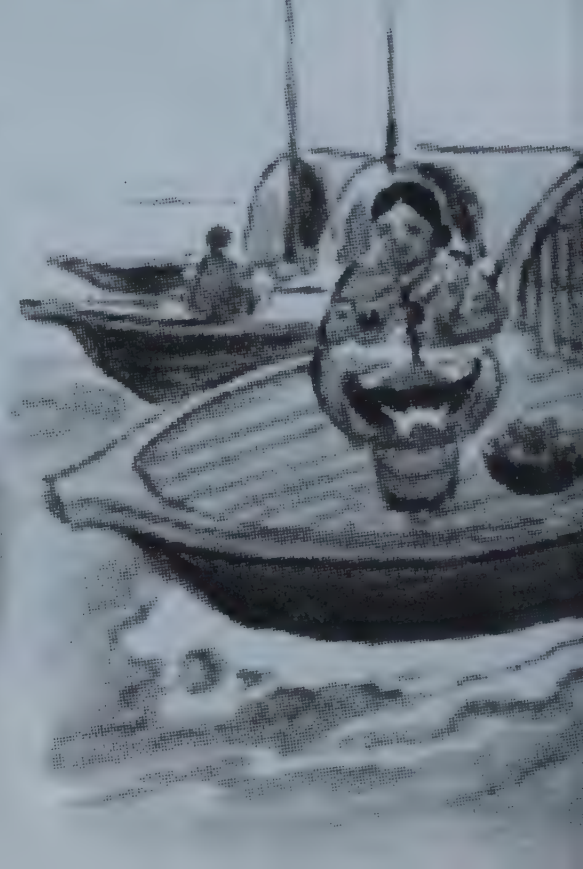
"Hmm, but you said that there is no need to build houses! Staying outdoors is fun!! So we have to go now, food is ready" – Papa laughed.



"Well, we need a house, I agree. But staying outdoors is fun."

"I agree. We will spend next Sunday at the zoo"

"Yaaa"- some squirell ran out of their 'holy' nest!!



Why do we need a shelter ?

A shelter is a place that covers, protects, provides safety and gives privacy of a group or individual.

People need shelters to shield them from extremes of cold and heat, as well as from sun, rain, snow, and wind. Man also needed shelter to protect themselves from predators.Tigers, lions are the predators living on land, can u find out predators living in water.

People also built shelters to live in an environment of their choice.

Don't you fuss when you see that your room is in a mess, or you have to sleep on a bed which is uncomfortable. So human beings, unlike other animals, give importance to the comfort factor of the place they live in. So shelter would also mean something that would give a sense of delight to its inhabitants.

We know houses are built on land. House-boats in Kashmir float on the Dahl Lake.

The 'pagoda' style architecture of Japan.

Houses in cold climate are characterized by stilt roofs at different levels as these houses in Canada.

Low cost houses made of wood and grass in Africa.

These colourful and beautiful houses of Greenland resemble those toy houses with which you used to play as a child.

Houses in the rain forest area. Do you know the climatic conditions of the rain forests? Does these house suit the climatic pattern?

Look around and make a list of various kinds of houses that you see. Share with your friends.

People all over the world accommodate themselves in houses that match with the climatic conditions, material availability , and also their economic conditions. This may help you to find out the reason behind **"how their houses look"** .

"But Papa, besides living, houses serve other purposes too."

"Good observation! Buildings were built to serve various purposes even in the distant past. In the Indus valley civilization, we see the Great Bath, granary , public administrative buildings other than the dwelling houses.

In Rome, we see Colloseum, a place for entertainment, the scale and character of which varied from the houses meant for residential purpose." – Papa replied, showing a picture of the Colloseum.

We have types of buildings for varied purposes :

- Residential (like Hotels)
- Offices (like Office Complexes)
- Markets (like Shopping Malls)
- Entertainment (like Auditoriums)
- Educational institutions (like Schools/Colleges)
- Religious (like Churches/temples/mosques etc)

Can you give some more examples?

Let us make use of the following chart.

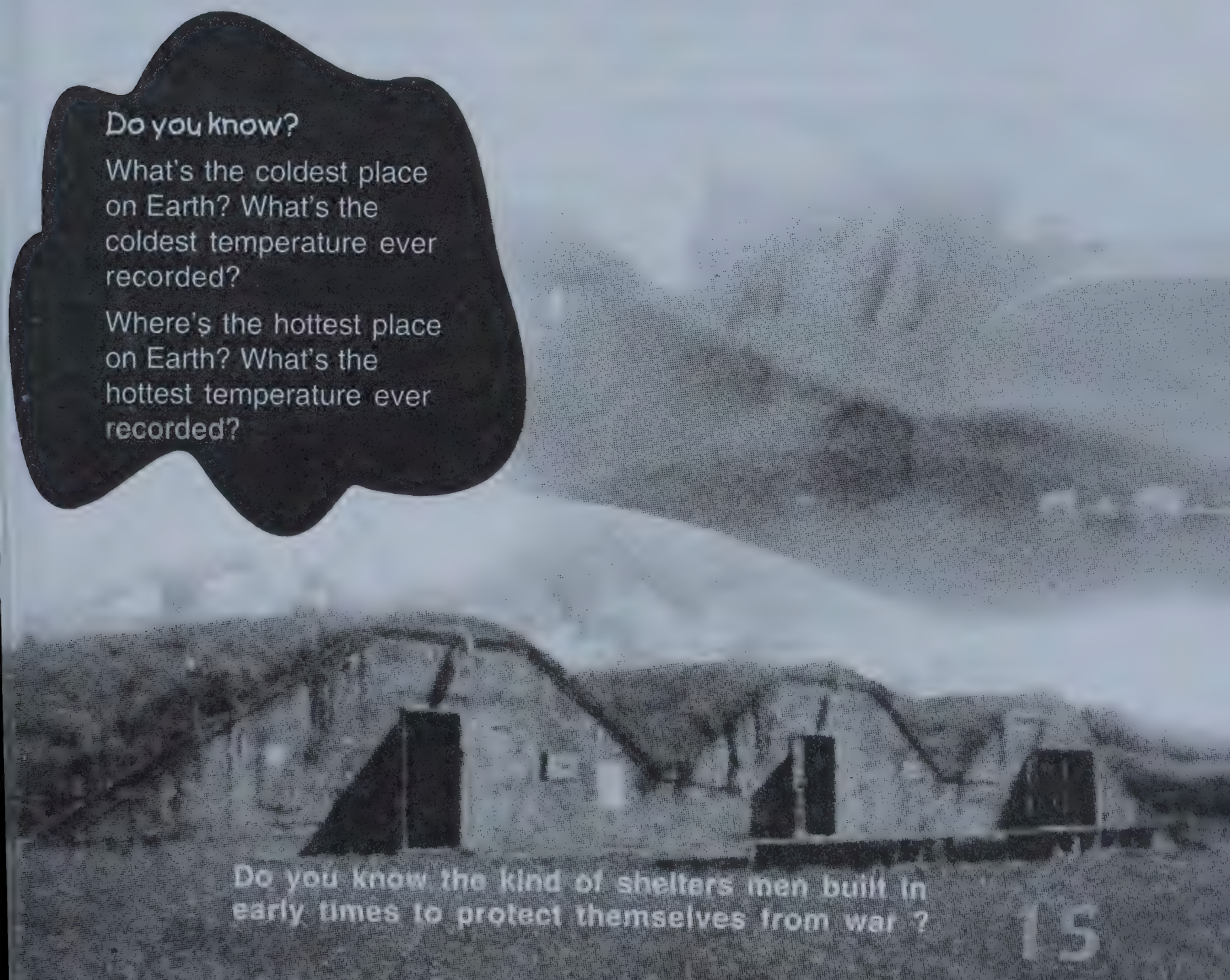
Type	Purpose	Size	Basic Facilities	No. of people at a time	Special criteria

Can you establish a relation between the purpose, structure and the scale?

Do you know?

What's the coldest place on Earth? What's the coldest temperature ever recorded?

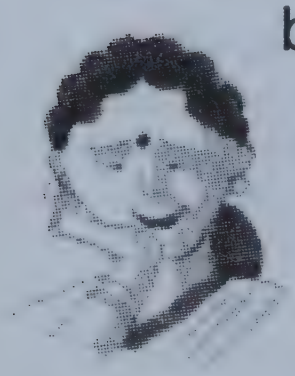
Where's the hottest place on Earth? What's the hottest temperature ever recorded?



Do you know the kind of shelters men built in early times to protect themselves from war ?

Chapter 2 History of houses

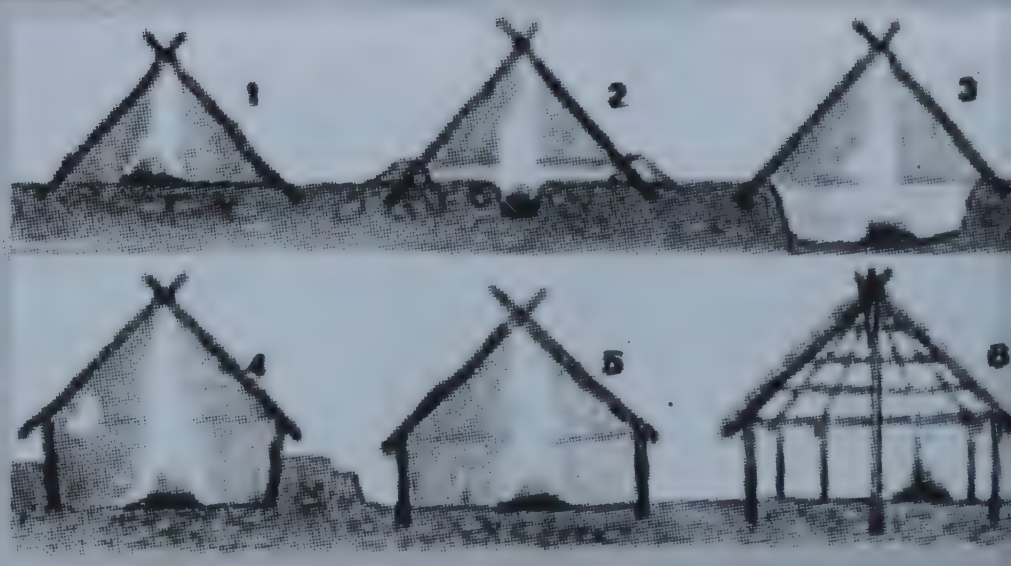
Sunny read in his book, that long long ago, man used to live in the caves! But how? How did they cook in the darkness of the cave? Were there any windows? Or doors? What happened when wild animals tried to get into the cave? Sunny asked Ma, "when did human beings start making houses? And what were they like?"



"It is difficult to trace the first house built by men."

Inside the caves it was impossible to make an oven for cooking. Guess why? So they generally set up a camp at the mouth of the cave or on a rocky ledge nearby. They may have slept in the caves, but it was on the threshold that they gathered to talk, to fashion their tools, to cut up the spoils of hunting, to prepare their meals, and even to bury their dead.

After few thousand years, the first appearance of dwellings which could probably be called houses came into being. They were built in regions where the soil was fertile enough for cultivation.



Primitive hut with a fire made on the centre of the floor (**1**); hut with hollowed out hearth in the centre and with perimeter walls reinforced (**2 and 3**); hut with walls and foundations (**4 and 5**); fully evolved hut (**6**).

“Have you seen this picture ?” Ma pointed out on the wall.

“Yes, a bunch of animals running away.”

“Do you know what is special about it ?”

“No Ma, but it looks as it drawn on a rough surface”.

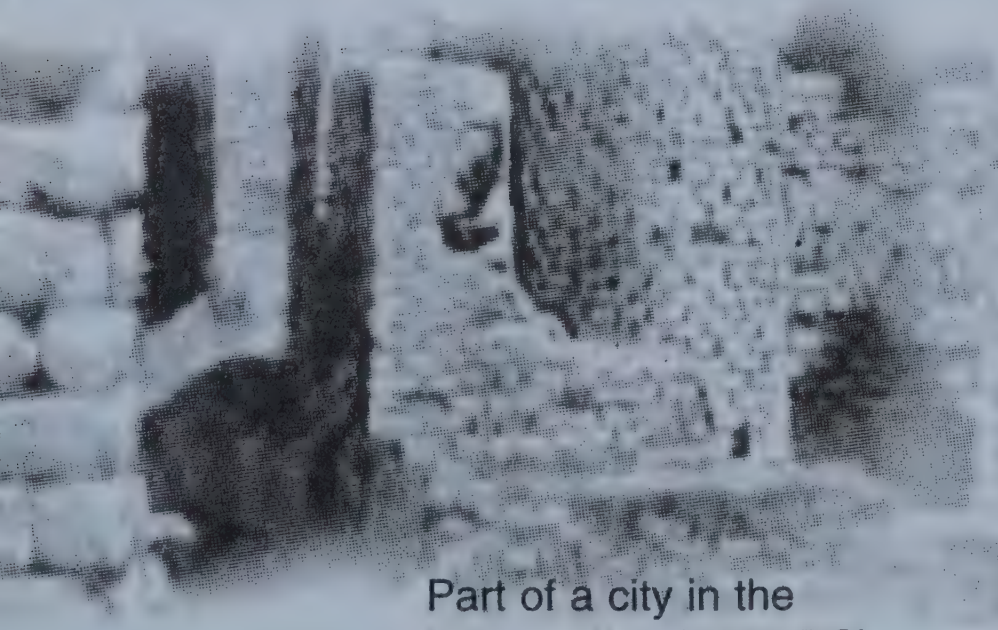
“Very good!! Prehistoric people made this painting by mixing vegetable, plant and earth pigments together

A peculiar town made of prehistoric lake dwellings, or palafittes. These were houses built on the stilts at the water's edge or on marshy ground, to give protection from wild animals or enemy tribes.

with water or animal fat. The early painters derived their colours from the earth which were mostly browns, reds and blacks. It is an imitation of that. Isn't it beautiful?" Ma replied.

"Ma what happened after that?" - Sunny wanted to get back to the history.

"After huts, man made buildings made of baked bricks. Have you heard about Indus valley civilization? Long before the birth of Christ? Now it is in Pakistan. The whole city was made of brick."



Part of a city in the Indus valley (2000 BC).

When was brick first used?
Since the very early days of their history, man had been making bricks of clay or other materials for use in buildings. The Tower of Babel, for which, according to the Old Testament, 'they had brick for stone', was probably a brick temple. People who lived in ancient Egypt built their houses from both sun-dried and kiln-baked bricks.

"Brick is a very important invention in the history architecture. Now a days, though there are lots of alternative materials, we are still using brick as a primary construction material. Bricks need good quality mud. So all the brick factories are on the bank of the river. People, who take out soil for the purpose of making brick, which create lot of damage to the rivers causing flood and other destructions" – Papa encroached in the discussion.

"Anyway, when you are talking about Indus valley, we should not forget about the wonderful Egyptian architecture - the Pyramids!!"

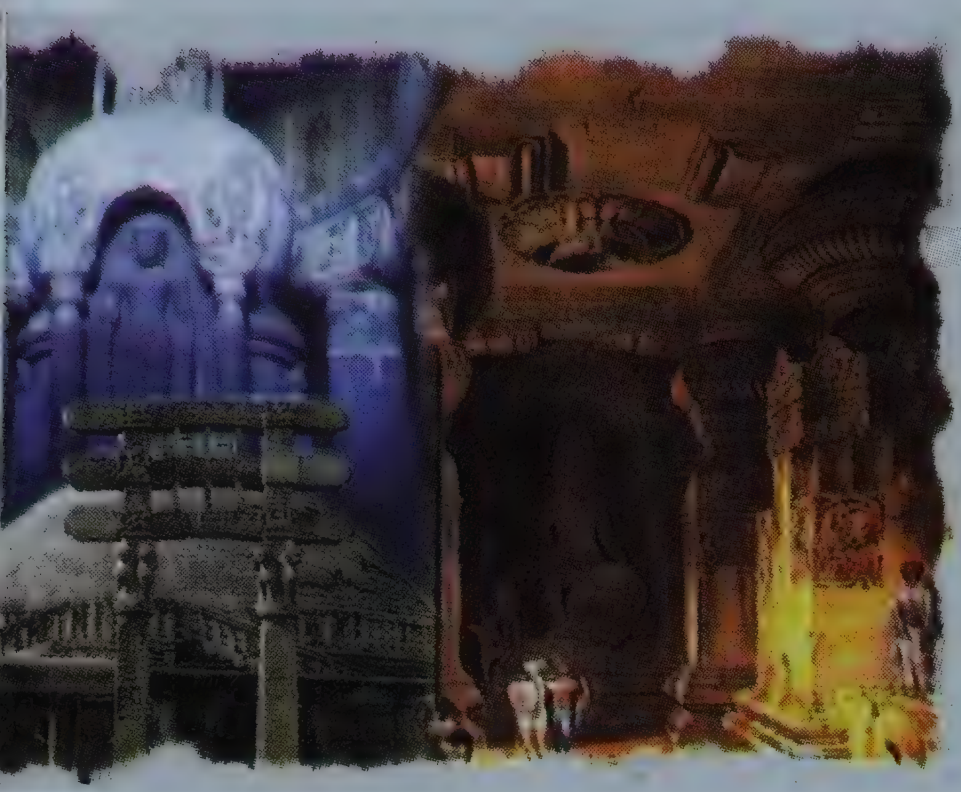
The pyramids roughly covered a base of 9 acres. This may give us the idea as to how gigantic they were. The monuments of Giza and the entire Giza valley stand as a marvelous reminder of the skill executed in the creation of the pyramids, and are truly fabulous to see.

Do you know the dimensions of the sphinx?
The Paws : 50 feet long
The Head : 30 feet long, 14 feet wide
The Entire Body : 150 feet high

" Ma please tell me about the ancient architecture of India"

Indian architecture is as old as the history of the civilization. The earliest remains of recognizable building activity in India dates back to the Indus Valley cities. Among India's ancient architectural remains, the most characteristic are the temples.

In ancient India, temple architecture of high standard developed in almost all regions. The distinct architectural style of temple construction in different parts was a result of geographical, climatic, ethnic, racial, historical and linguistic diversities.



The **Rock-cut structures** present the most spectacular piece of ancient Indian art specimen. Most of the rock-cut structures were related to various religious communities. In the beginning, remarkable Buddhist and Jain monuments were produced in areas such as Bihar in the east and Maharashtra in the west. **Chaityas and Viharas** are those rock-cut structures that were hewn out for Buddhist and Jain monks. Chaityas were places of worship whereas Viharas were residence of monks.

Some of the famous and prominent caves are at Nashik, Kanheri, Gaya (Barabar Hills), Bhaja, Nagarjunikonda, Badami, Elephanta and Ellora. These caves house some of the amazing murals, sculptures and architectural structures.

Maharashtra is home to the spectacular and amazing **Ajanta and Ellora** group of caves. In all there are 34 caves at Ellora and 29 caves at Ajanta.

The Rathas at Mahabalipuram are yet another great specimen of rock-cut architecture in ancient India.

Another type of Architecture which has mingled with our culture is the Muslim or Islamic Architecture, and the Great Moghals left their foot prints even in their unique architectural style. The Taj Mahal is the most remarkable.

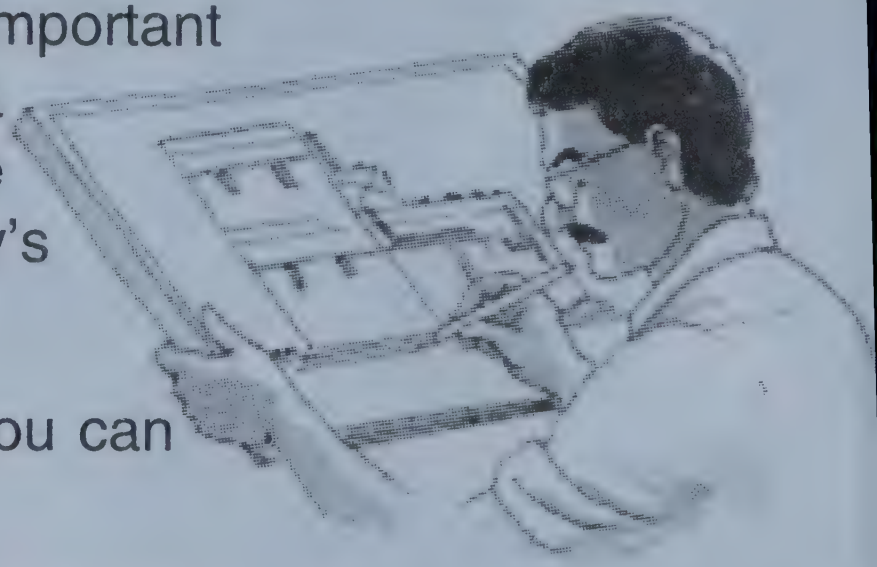
Do it yourself

Collect the photographs of different pieces of Indian architecture, group them and maintain an album. Write down about the striking characteristics and share it with your friends.

Nowadays many people live in blocks of flats. Modern blocks are often built of reinforced concrete. This consists of large sections of concrete with steel rods embedded in it to give added strength.

Can you think of houses that do not need a permanent patch of land, that can move, in other words mobile dwelling houses, other than caravans.

Some
amazing
modern day
architechture



"Sunny, what is the most important part of our house?" – Papa asked while drawing the picture of a house. Sunny's Papa is an engineer.

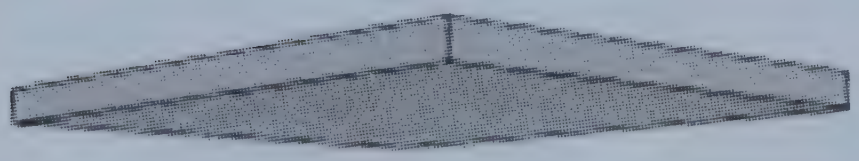
"Window papa, so that you can see everything".

"But if the walls were not there, who would need a window?"

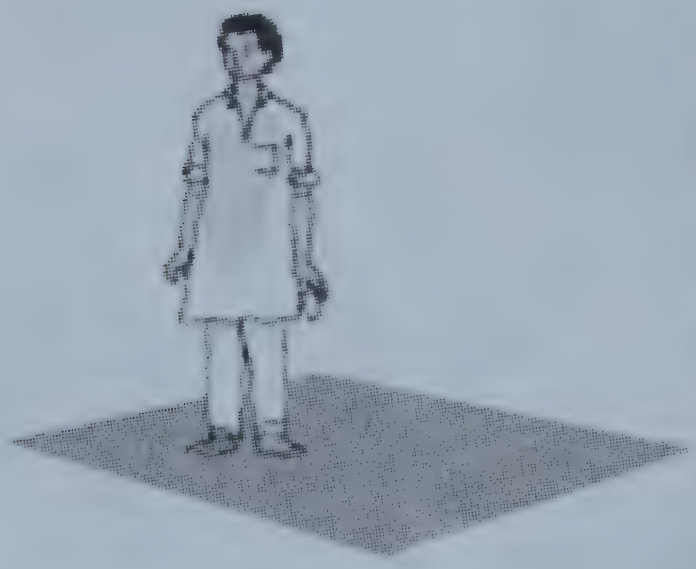
"Well, then walls are the most important."

"When you are walking on the road on a hot summer day, you need an umbrella to avoid the scorching sun rays. On a rainy or windy day you will feel lucky to house yourself under a shade."

"Ok, now I think roof is the most important part."



"Good. So let us think this way, in your house there is a **roof** that covers the living areas."

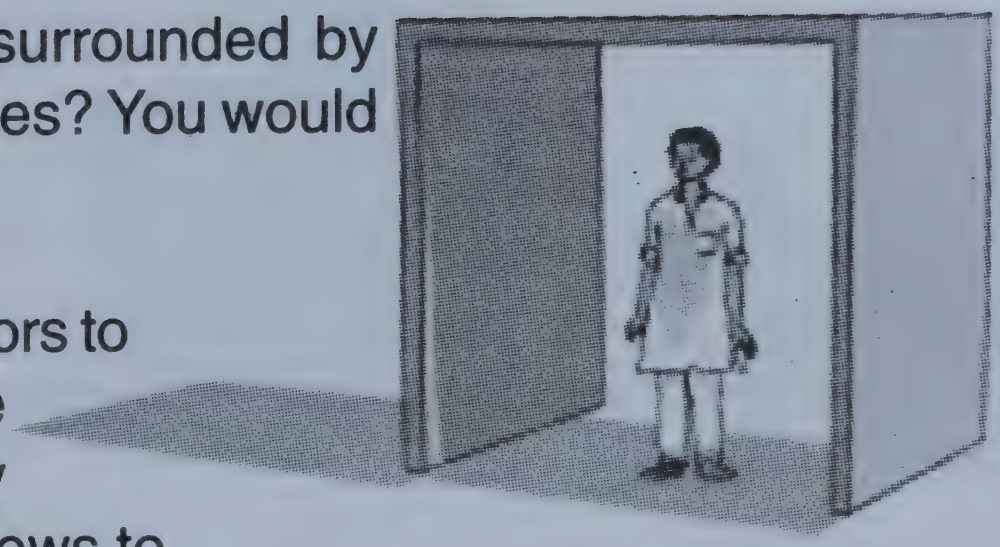


"But how can the roof above your head hang without any support?"

"True. Therefore you need walls to support the roof above your head."

"But here comes the next question. Could you think of living

in a room that is surrounded by walls on all four sides? You would feel suffocated."



"Papa, we need doors to get inside the space enclosed by the walls and windows to see the world outside and get fresh air."

Do you know?

The height of a door should be at least 2100mm or nearly 7 feet. Can you say , why?

"Sunny, do you know the story of 'The Three Little Pigs and the big bad wolf."

"Yes Papa, The first little pig built his house from straw, which the

wolf blew down and then ate him up. The second little pig built his house

from sticks, which the wolf again blew down and then ate him. But the third little pig used bricks to build his

house, which the wolf could not blow down. So the wolf entered down the chimney, fell into a pot of boiling water, and the pig ate him!"

Sunny and Papa both laughed aloud.

"Good. **The story tells how the smart little pig anticipated what the wolf could do, and accordingly selected his materials wisely to build his house.** The other two did not anticipate this and paid for their mistake dearly. It could be subjected to, when we design a bridge or a building, we always try to calculate the forces, so that the bridge doesn't break down by the wind pressure or by vehicles traveling over it or by its own weight!"

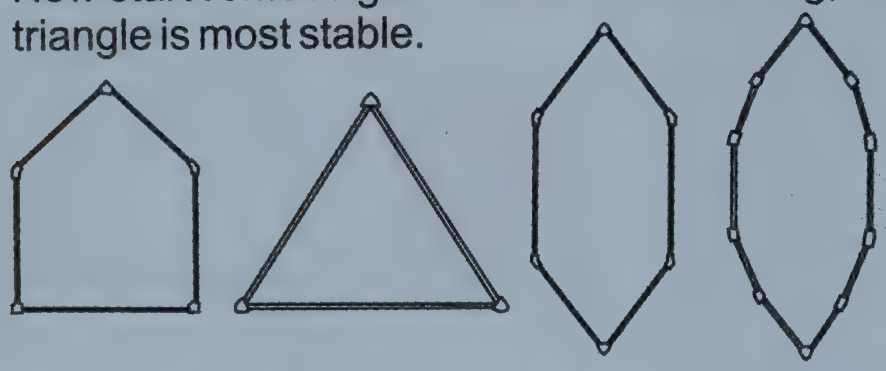
The stability of man-made structures depends primarily on two things –

- the strength of the materials (e.g. straw, wood, brick) used
- the way that they are arranged together to form the structure (e.g. bundled, nailed, mortared).

Structural materials get their strength and stability from the way that their atoms (i.e. bricks) are packed together (i.e. stacked) by the force of their atomic bonds (i.e. mortar) so as to resist being pushed out of shape by external forces (i.e .wolf puffs). Certain structures are inherently more stable than others regardless of what they are made of.

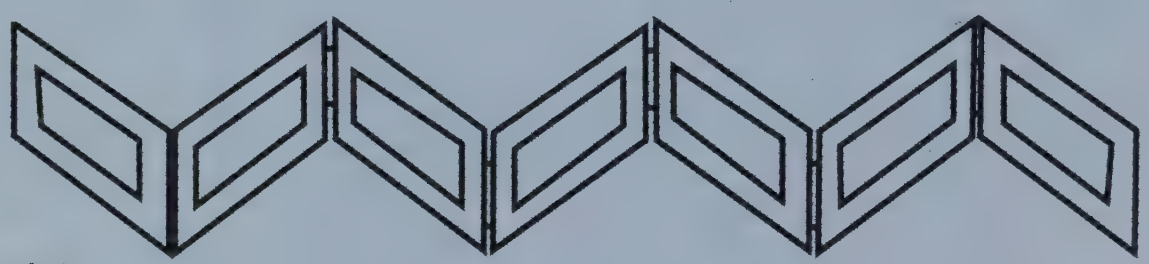
Activity Page

Build a chain made from six small squares that are joint together by flexible pin hinges. The chain is obviously not very stable, since both ends of it and the middle can be moved in any direction with the slightest push. Now join the ends of the chain together forming a six-member hexagonal ring. Notice that the ends of the chain are no longer free to move independently of each other and the movements of the individual members are confined to the ring's perimeter. Now start removing members from the ring, one by one. You will see that the triangle is most stable.



If you take two out of this chain, and try to make it stand straight on the floor, it will fall. But if you make an angle, it won't fall. Why?

For a building the forces and reactions



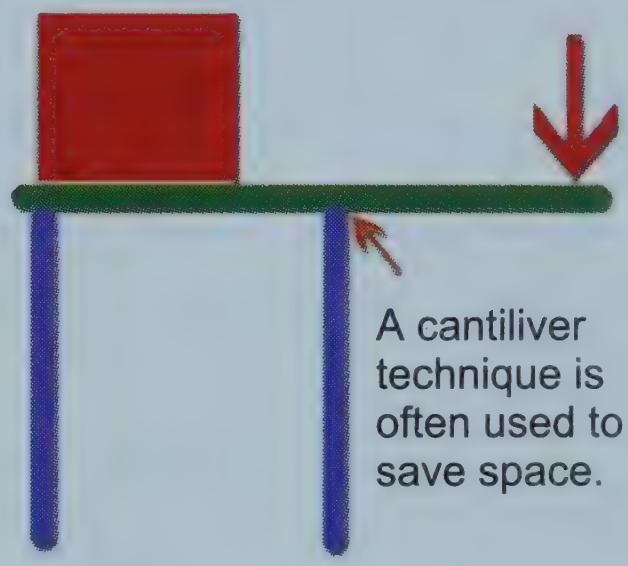
A building must resist
the stresses through its structural members called columns, beams, foundation etc. by the loads acting on it.

1. Dead loads include the weight of the structure itself plus all of the fixed equipment.
2. Internal live loads include the people, moveable furnishings and equipment, and vehicles occupying the building.
3. External live loads include wind, rain, snow, earthquakes, etc.

Besides keeping the building from being permanently damaged by these loads, the structure must be strong enough that no part of the building is significantly deformed by them.

The columns are the vertical members that withstands the forces arising from the different loads as discussed above acting on the building. Which in turn is transmitted through the walls and other members to the building foundation and finally to the ground or the earth over which it stands and so the building is stabilized by the reaction force which the earth induces in the structure.

The beams transmit the load, exerted by the roof, to the columns. The columns, ultimately pass it on to the ground through the foundation of a building.



A cantiliver technique is often used to save space.

Can you recall Newton's third law?

Rabindra Setu or Howrah Bridge is a fine example of cantiliver hanging bridge.

Next day was a holiday for the school. Sunny woke up early in the morning. Papa promised to take him to a building site. What a pandemonium! Big machines! Lot of people running to and fro on various business!! Sunny draws a picture of the site. He tries to note down the people involved and materials required.

"Sunny, be careful!" – Papa warned. His voice was not heard clearly because of the sound of the machines.

The basic building materials

Cement is a binding material that harden by reacting with water to form a water-resistant product.

Mortar is a mixture of cement, sand and water and is used to bond bricks or stones. Mortar is also used as a render on walls for reasons of providing weather resistance or decoration.

Concrete is a durable building material made from a mixture of cement, coarse & fine aggregates, and water which can be spread or poured into moulds. It hardens to form a rock-like mass.

"Perfect, but these are not the all. To complete a house, you need Water supply, Electrical Services and drainage system. Water as you know, is the most important thing in our daily life. But remember, it is always better to use less of ground water – we are running short of it. We should store rain water and use it for future." Papa said.

"But, is it enough Papa?"

"Of course, but certainly it depends on the area and the number of users. But saving a single drop of water is important. Efficient drainage system, having a proper waste disposal plans is important too. Electricity was not very fundamental earlier, but with the advancement of our society, it has also become important."

In the evening, Sunny came up with a question.

"Papa, we have seen a concrete house. But what about houses in the rural area? What are the material used?"

"Very good question. In rural areas, people use locally available materials. But the idea is the same. In a mud house, they use trunk of trees which is very stable. Instead of rods, they use bamboos. Instead of bricks, people use stone blocks. Instead of cement, they use mud mixed with ricehusk."

People involved in the process of making buildings?

- Architect
- Structural Engineers
- Electrical Engineers
- Contractors

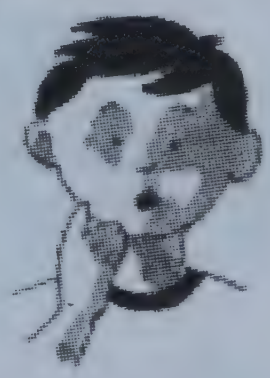
Do not forget the people who give their hard labour

- mason
- painter
- plumber
- carpenter
- electrician

Can you tell us about the specific activities of each of the above mentioned persons?

Chapter 5 The building design

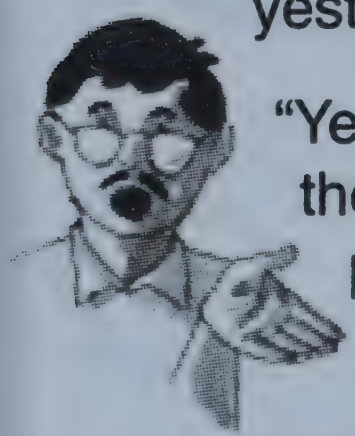
"Sunny, we know that people live in different types of houses. Can you tell me what are the things that decide the type of a house?"



"Yes Papa, first is the place where it is built"

"Yes, that means its climatic conditions, geographical position and location"

"You were telling me about different types of material yesterday."



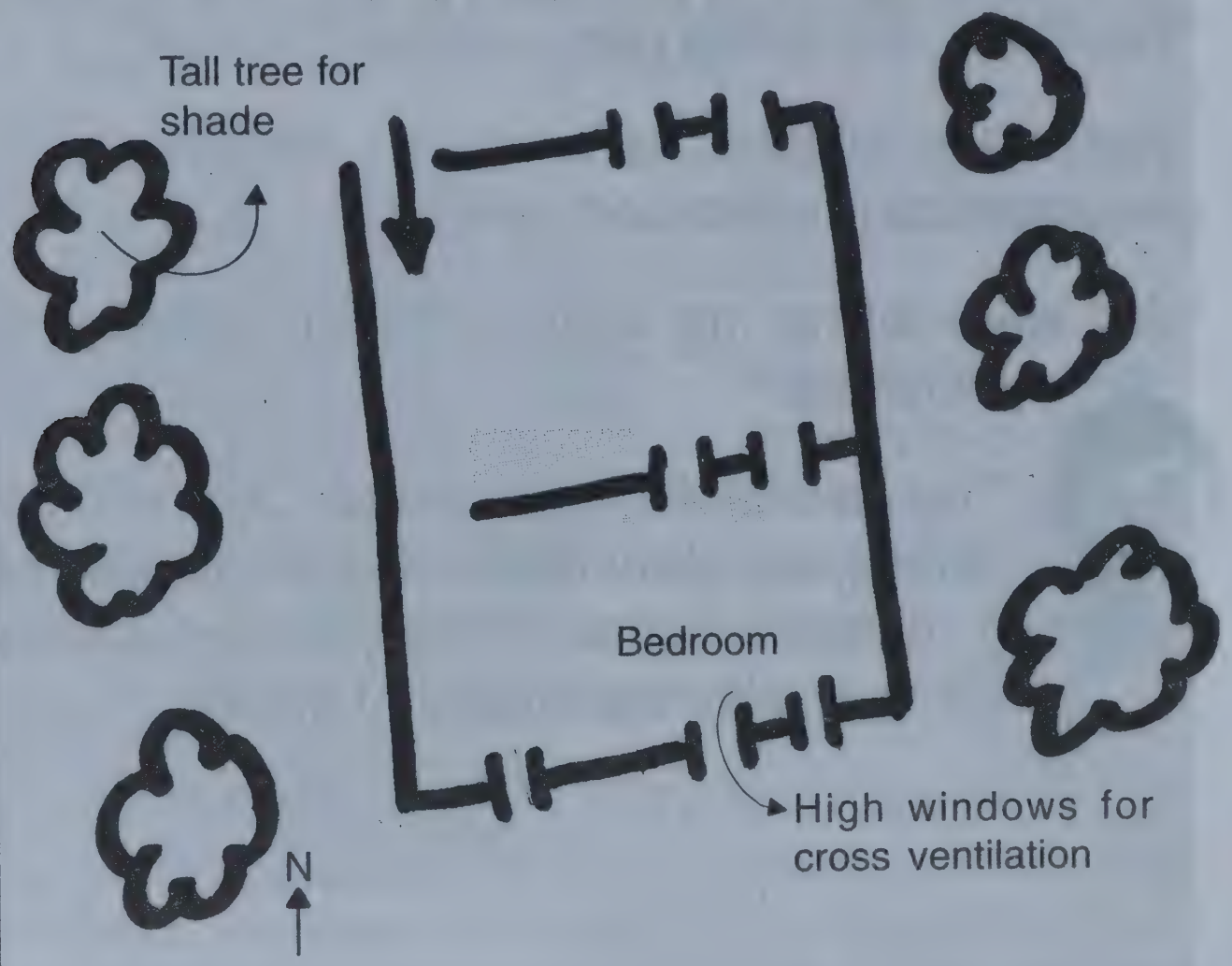
"Yes, availability of material. Over and above all these, are other factors like availability of funds, purpose, number of people to be accomodated and also the choice of design.

For hot-humid climate

It is important to design buildings, whose **structure and interiors are best able to keep warm air out**. That is why it is important for the buildings structures to have effective and proper ventillation which allows the air to circulate inside, keeping the inside cool.

- windows opposite each other to allow cross-ventilation. Keep windows on east and west walls to minimum.
- long, narrow floor-plan in the sleeping zone to maximize ventillation in bedrooms;
- living areas with high ceilings, to maximize air movement and reduce heat.

- elevate house to catch the breeze.
- boundary fences should not block airflow
- in a new subdivision, the spacing of buildings should be carefully considered to avoid obstruction of the wind;
- using pale colours for walls and roof, to reflect the heat of the sun;
- metal roofs which cool rapidly at night. Daytime heat gain can be



Having extensive plantations on the exterior facade not only enhances the greenary, but also blocks the sunrays, keeping the insides cool in a temperate climate.

minimised by using sheeting with a reflective coating on its underside.

For Arid Desert

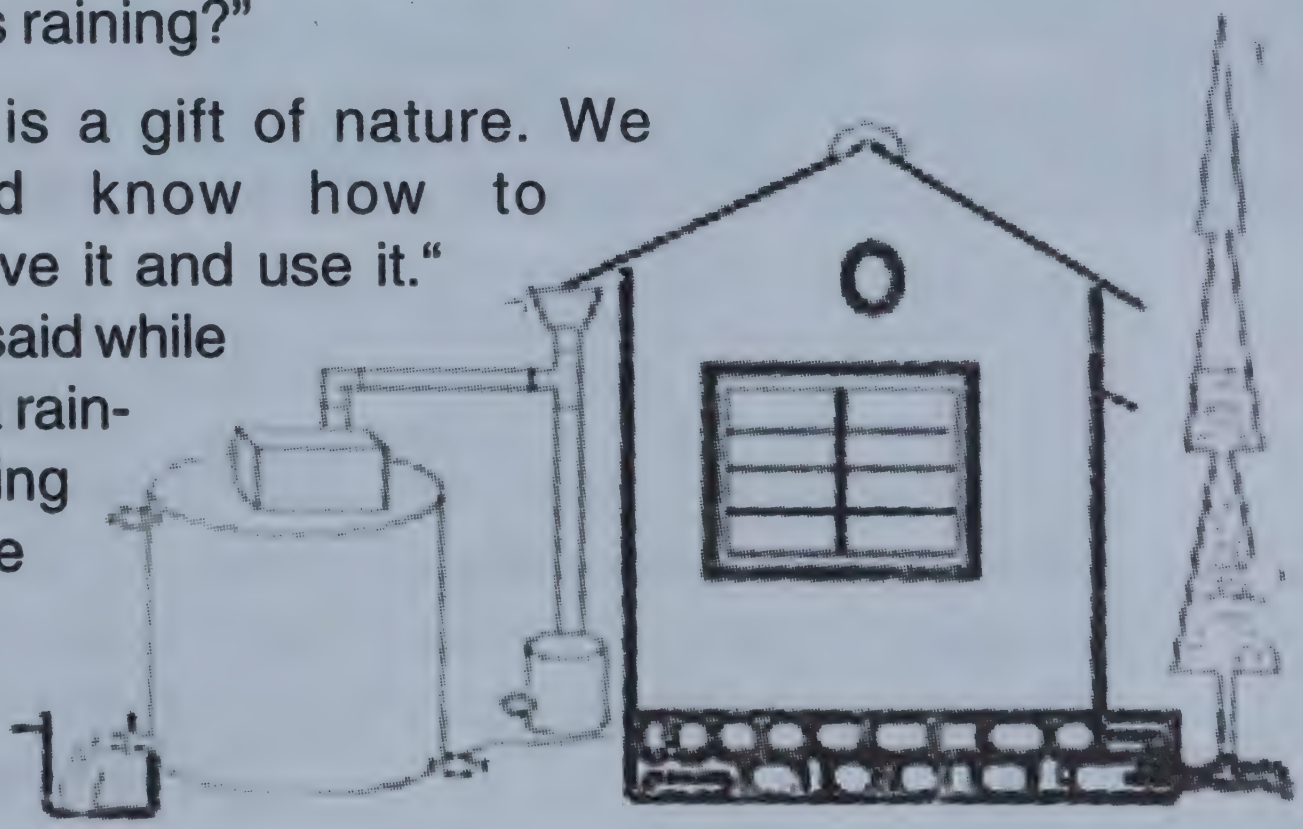
- In arid, desert regions, buildings are designed with **flat roofs, small openings, and heavy weight materials**. These materials include dried mud in rural areas and reinforced concrete in urban areas.
- The thick exterior roof and walls help to absorb temperature fluctuations and, therefore, keep internal temperatures from rising above the outside surface temperature.
- A white or light colored roof will stay approximately the same temperature

as the outdoor air during the day, and 6° to 10° C cooler than the outside air at night.

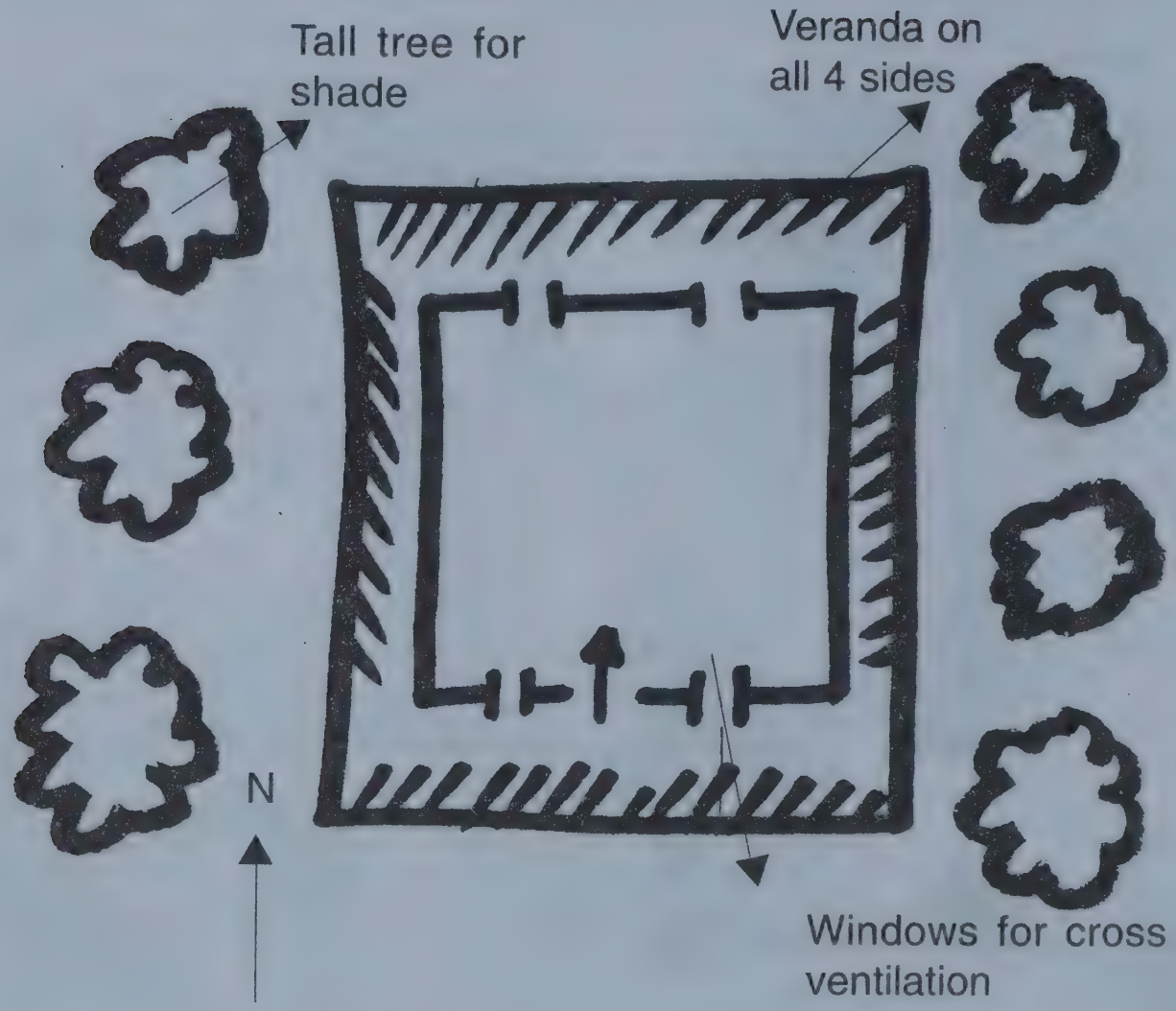
- Courtyards, patios, and verandas are other common features of buildings in hot climates

"Papa, what would happen to a place where it is always raining?"

"Rain is a gift of nature. We should know how to preserve it and use it." Papa said while drawing a rain-water harvesting structure model.



For hot dry summer, mild winter



Because of the intense sunshine we need: -

- Pale surfaces (especially the roof) to reflect the sun;
- The hotter the summer, the smaller the windows.
- Vegetation and verandahs around the house.
- Bedrooms should use light construction material, so that they cool off quickly at night;
- Through ventilation on summer nights is essential (check the prevailing wind direction on warm summer nights). Roof-mounted exhaust fans can cool buildings at night by extracting hot air and replacing it with cool air drawn in through open windows;
- Use solar pergola structure.

For the cold climate

The key is to reach the **good insulation and sunshine exposure**, which helps us to keep the warm air inside the building.

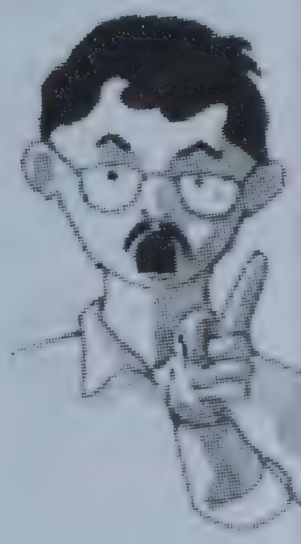
- To minimize and reduce heat loss, rooms should have low ceilings, thick stonewall, small windows, and centrally located heating.
- The difference between thick walls in cold and hot climates is that in hot climates the walls outside are meant to shade the interior from the intense heat, whereas, in cold climates the walls are meant to insulate and keep the heat in.
- Many settlements cluster their houses close together facing the south in order to minimize heat loss.

Sunny heard that Ma is asking Papa about repairing the roof, which has a patch.

"Papa, what is this patch?"

"This ugly patch is created by damp, Sunny. A defective roof-leakage causes water to seep into walls or roofs and make a damp patch. This leakage might be the result of using bad materials!!"

"That reminded me of some important things you should know Sunny. Not only water, but there are other factors which might cause damage to a building. **Heat** causes expansion of materials of the building. **Rain** can cause dampness. Exposure to sunsine might cause the paints of the walls to fade. The **snow** make water freeze and expand, so it can create crack. And we should always be mindful about the possibility of **animal and pest attacks**."



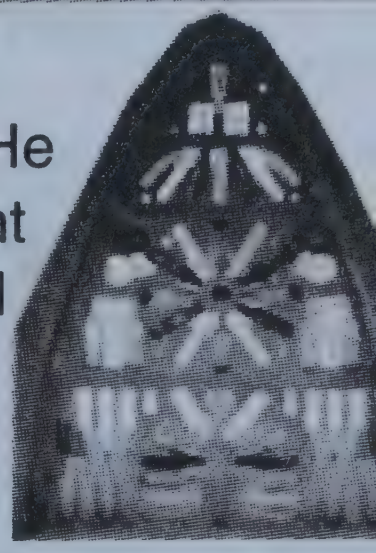
"Oof! So many things to remember" –
Sunny was tired!

"And don't you forget about man made factors. The **wars, theft, pollution, vibration, Fire** etc. All of these can be of serious damages. Have you heard about Tajmahal? What happened to the proide of India due to pollution?"

Can you complete the list?

Cause	Effect on the building	Possible Design to avoid/prevent
Elephant Attack		
Damping		
Big tree		
Theft		
War		
Vibration		
Fire		
Sunlight		
Polliution		

Chapter 6 The 'green' house



Sunny was quite curious about **green buildings**. He read about them in the magazines which Papa brought home. He thought that the buildings possibly looked green.

He asked Papa, "what is a Green Building?"

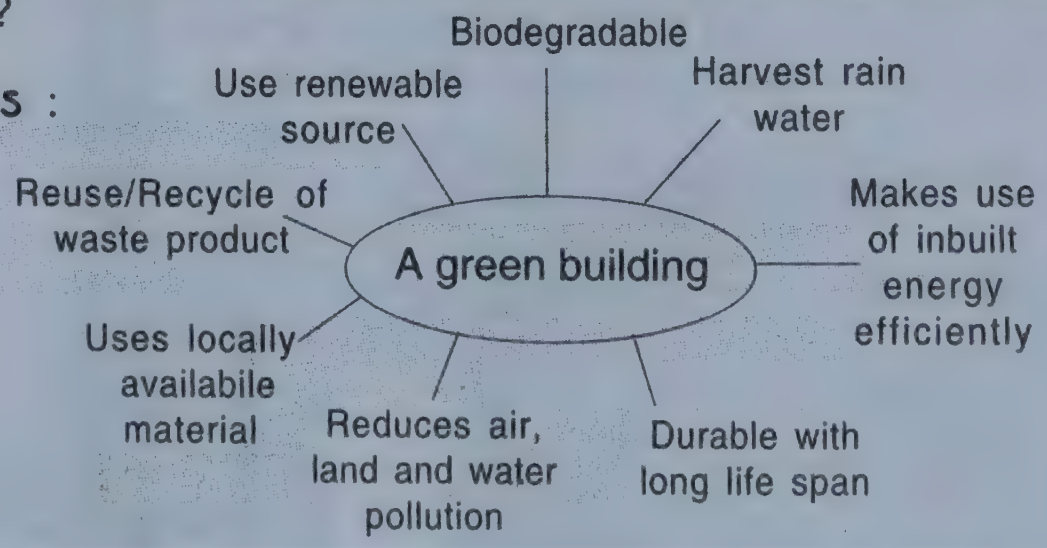
Papa said "Sunny, India is a rich country in biodiversity, cultural diversity and heritage. Heritage of coexisting in harmony with nature and natural elements, a rich history of sustainable usage of natural resources".

But it is still developing, it is the second most populated country and has some very thickly populated cities. We are now in the crossroads of development and urbanization. Sometimes we contradict our heritage; sometimes we close our eyes to our age-old traditions of keeping harmony with nature. The land filling, unplanned expansion of city vertically and horizontally, cutting down trees for creating space – are some of the major problems which nature has started protesting and revolting against in her own way!

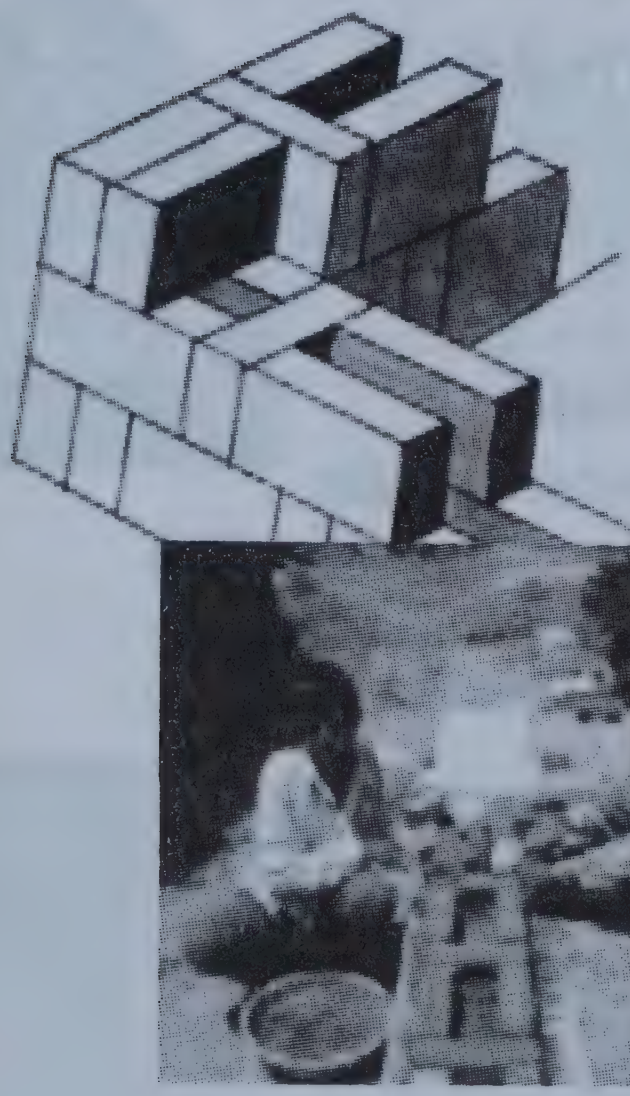
We need to keep in mind that India is an underdeveloped country where 2/3 rd of our countrymen are still struggling to get a two square meals a day. So ethically, is it worthwhile to spend large resources for making and maintaing a single construction?

A green building is :

- Cost efficient
- Energy efficient
- Eco friendly

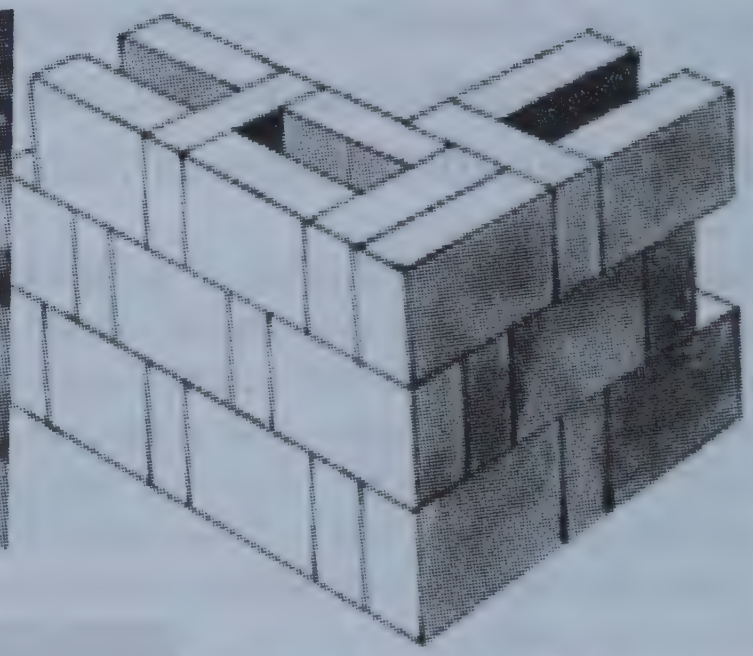


Some useful techniques



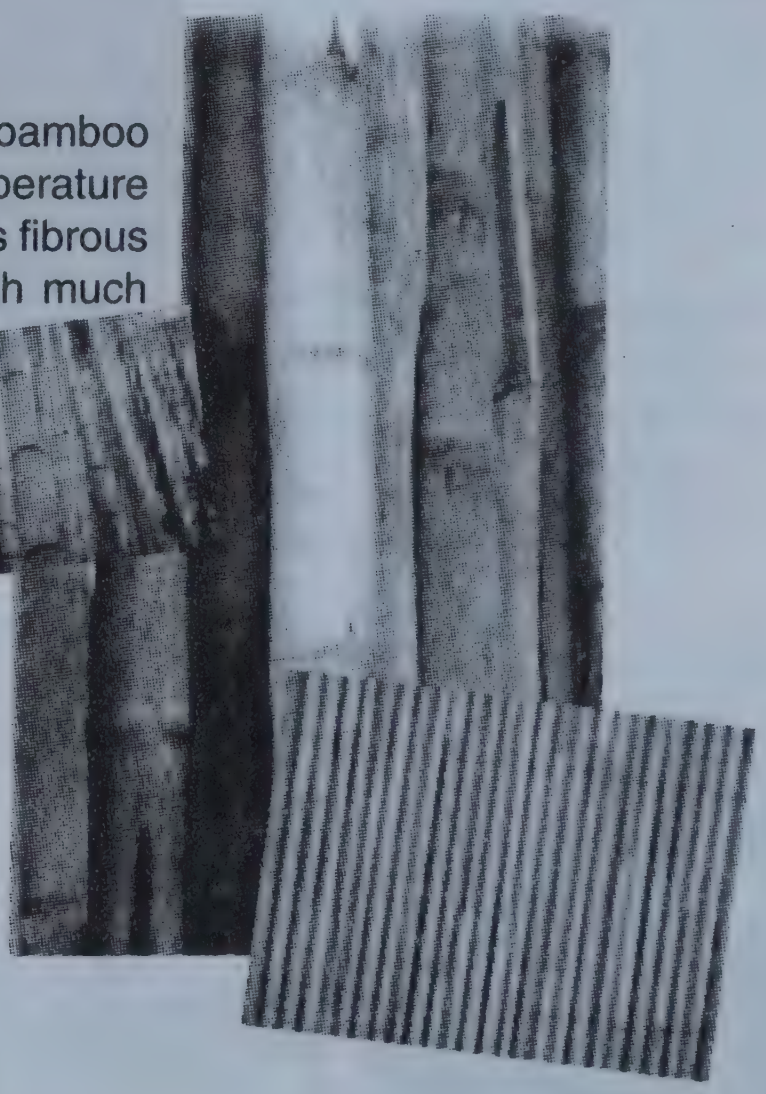
Rat trap

Walls Should be made of 'rat trap' or Chinese bonds of bricks, that supports the corbelled brick vaults and brick slabs with reinforcements. These techniques reduces the cost ,as the use of reinforced concrete is avoided and moreover provides better heat and sound insulation.



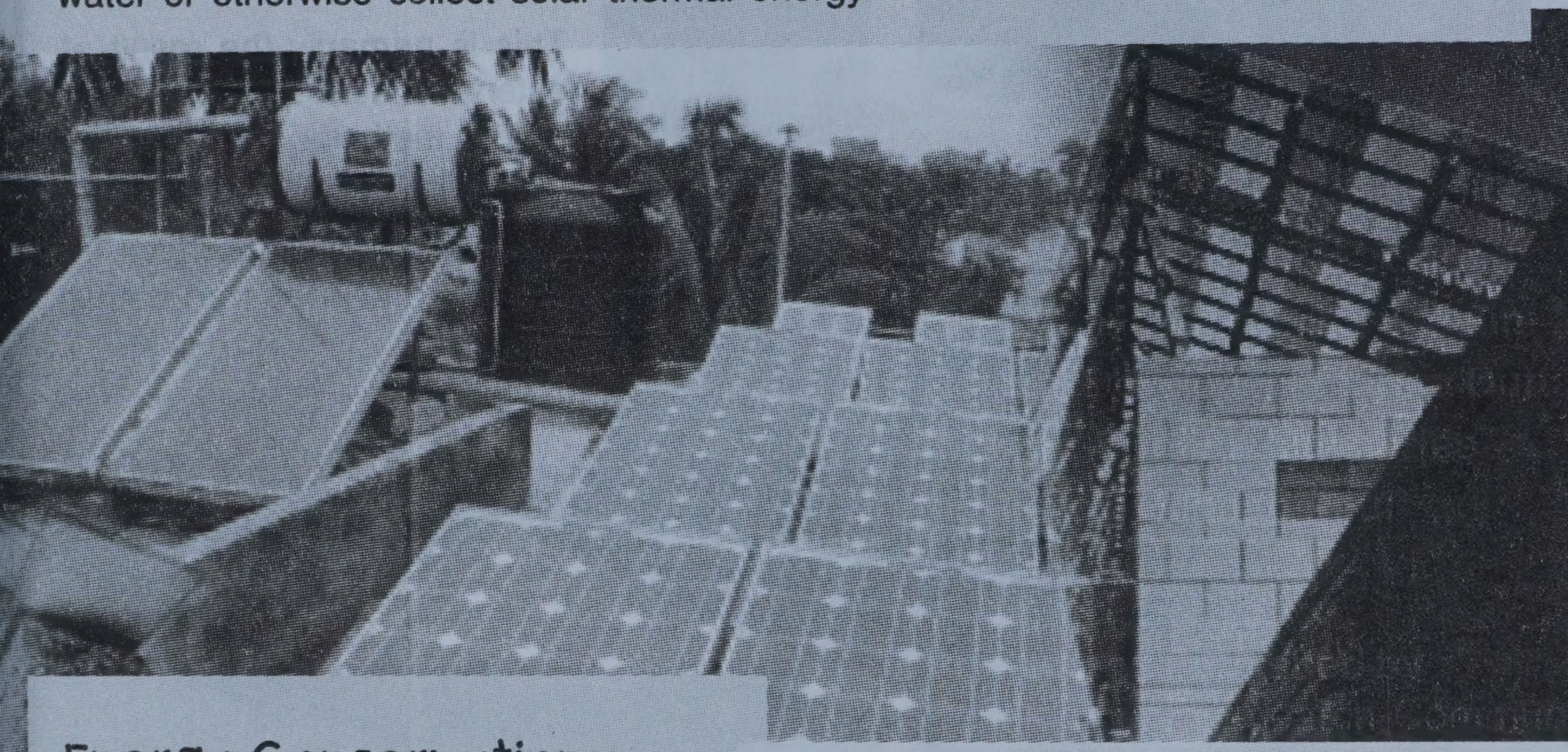
Bamboo

Being porous in nature, it is believed that bamboo absorbs less heat, maintains a cooler temperature than other materials of construction ,while its fibrous property enables it to withstand cracks with much ease.



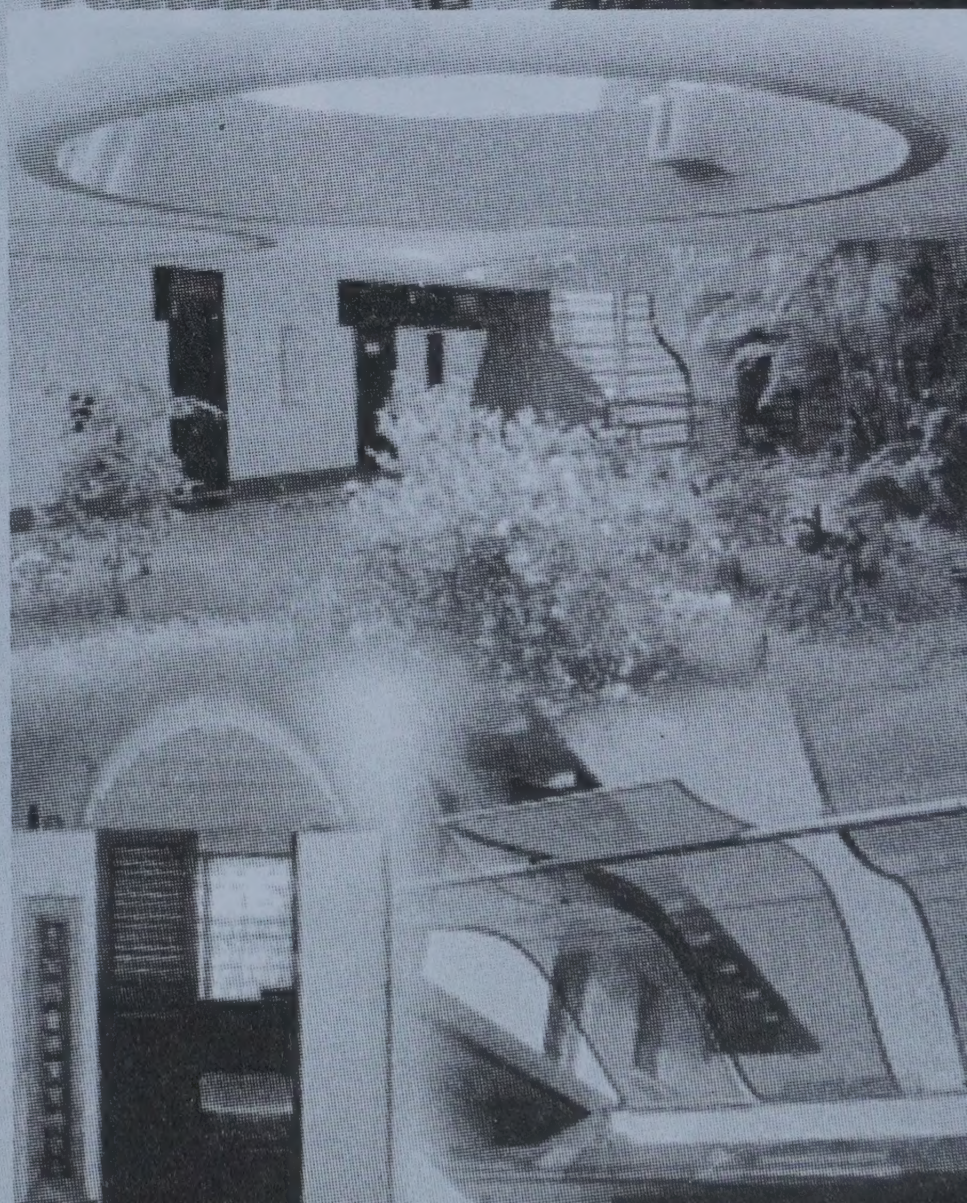
Solar Panels

Most of the energy we use in our daily lives are non-renewable and are about to finish. Using energies like solar and wind can save our planet. Solar Panel is a collection of solar cells used to generate electricity, or to a flat solar thermal collector, such as a solar hot water panel, used to generate solar hot water or otherwise collect solar thermal energy.



Energy Conservation :

- Use materials that require less energy during construction e.g. *pre-cast slabs*.
- Use materials that help reduce the cooling loads- e.g – *aerated concrete blocks*.
- Use fixtures & equipments that help conserve water *e.g. Dual flush cistern*
- Use products that conserve electrical energy – *e. g. CFL lamps*
- Use natural light as a substitute for (or complement to) electrical lighting.
- Use natural ventilation whenever possible.

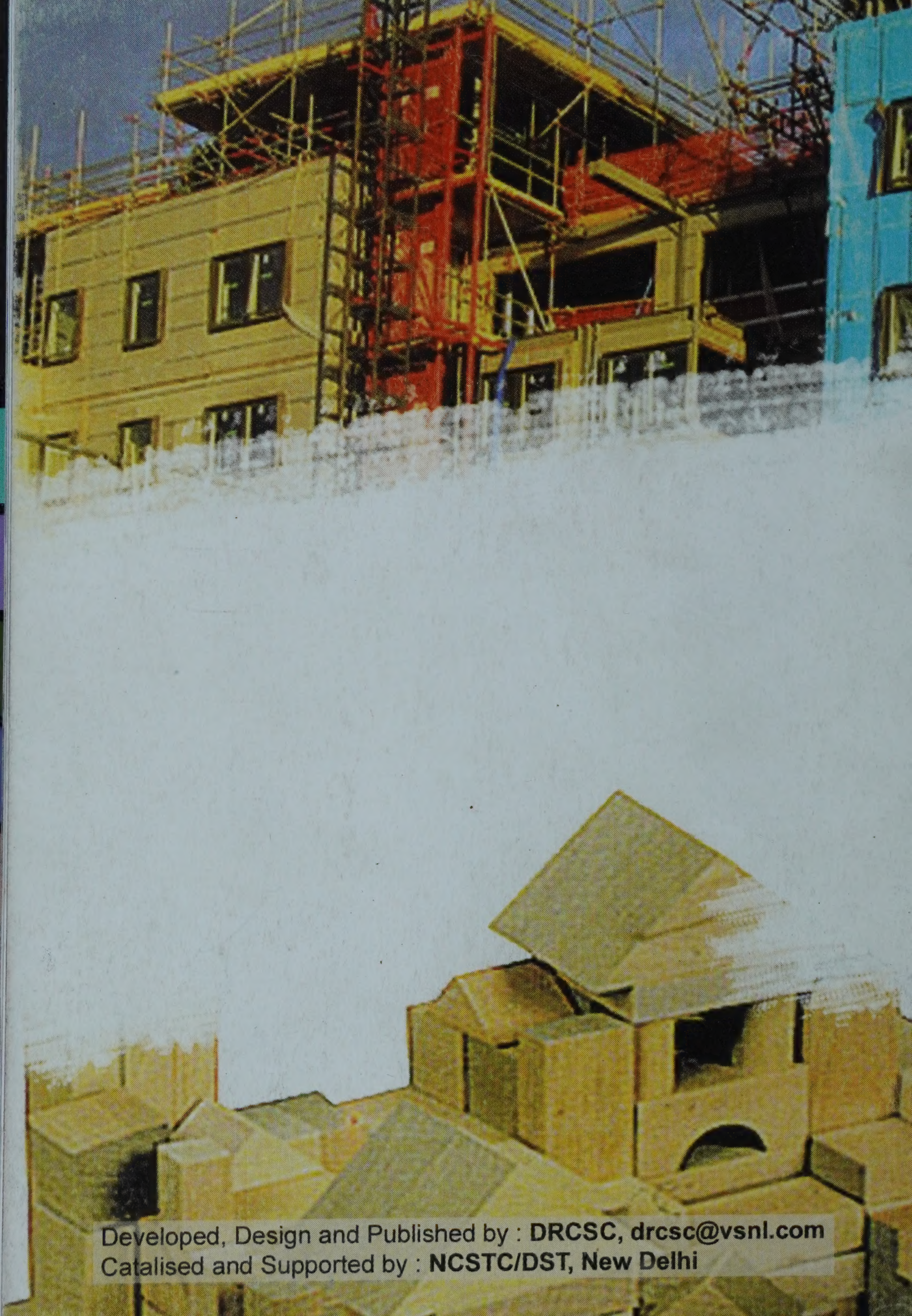


Rain Water Harvesting

Once Cherrapunji was famous because it received the largest volume of rainfall in the world. It still does, but ironically, experiences acute water shortage.

This is primarily the result of extensive deforestation. Aslo proper methods of conserving rainwater have not being used.

Nowadays buildings have its inbuilt rainwater harvesting structure.



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